## 1. ADMINISTRATIVE

**Project title:** Creating practitioner-driven, science-based plans for connectivity conservation in a changing climate: A collaborative assessment of climate-connectivity needs in the Washington-British Columbia transboundary region

**Award number:** G14AP00096

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## 2. PUBLIC SUMMARY

When the Earth experiences changes in its climate, wildlife respond by moving – species adjust their ranges to track changes in climate, moving out of areas that become too hot or otherwise inhospitable, and moving into areas that become newly hospitable. However, climate change is now proceeding so quickly that it is becoming difficult for species to move fast enough to keep pace. In addition, today's landscapes feature significant barriers to movement presented by human land uses (e.g., roads, cities, farms). Such is the case in the region around the border of Washington and British Columbia, where increasing development pressure and limited coordination of land and wildlife management across the border pose a threat to the future ability of wildlife to move as the climate changes. The Washington-British Columbia Transboundary Climate-Connectivity Project sought to address this problem by building the capacity of land and wildlife managers in the transboundary region to incorporate climate change and wildlife movement into their decision-making. The project paired climate scientists with land and wildlife managers from both sides of the border to work together to anticipate how climate change may impact wildlife movement and identify actions for addressing these impacts, so that their management of the landscape and the wildlife within it would be better prepared for future change. Products of this effort are freely available via an online tool that allows users to view and download reports, maps, and other project products describing potential climate impacts and management responses for a diverse group of plants and animals living in the transboundary region. Together, this effort and its products have enhanced the ability of land and wildlife managers in Washington and British Columbia to collaboratively respond to future threats to regional wildlife movement, enhancing the resilience of our shared species and ecosystems.

## 3. TECHNICAL SUMMARY

Enhancing ecological connectivity is the most frequently recommended strategy for biodiversity conservation in a changing climate, because doing so is expected to help species track shifting areas of climatic suitability across the landscape. In the transboundary region of Washington and British Columbia, increasing human land use and limited coordination of land and wildlife

management across the border present significant threats to habitat connectivity and climate resilience. The Washington-British Columbia Transboundary Climate-Connectivity Project was initiated to address these threats by building the capacity of land and wildlife managers to incorporate climate and connectivity science into their decision-making. The project paired climate scientists with land and wildlife managers from both sides of the border to collaboratively identify climate impacts on wildlife connectivity and actions for addressing these impacts, generating regionally and institutionally specific actions for maintaining transboundary wildlife movement in a changing climate. Project partners selected a suite of case study species and vegetation systems based on shared priority status among project partners, representation of a range of habitat types and climate sensitivities, and data availability.  They then developed conceptual models that identified the key landscape features and processes expected to influence habitat connectivity for each species, which of those are expected to be influenced by climate, and how. Project participants used these conceptual models to identify potential climate impacts on transboundary habitat connectivity for each species and vegetation system, and what actions could be taken to address these impacts. We summarized these impacts and actions in individual species' reports and an overview report, and made all reports and related maps and models freely available via the online mapping tool Data Basin. Working closely with practitioner partners throughout the project allowed these products to be credible, relevant, and accessible to their decision-making.

## 4. PURPOSE AND OBJECTIVES

As the Earth's climate changes, species are responding by adjusting their geographic distributions,[1] moving out of areas that become climatically inhospitable, and into areas that become newly hospitable. However, the ability of species to respond in this way is likely to be limited by both the rapid pace of change and widespread barriers to movement presented by human land use. For this reason, increasing ecological connectivity – the degree to which a landscape facilitates the movement of species and ecological processes – is the most frequently proposed climate adaptation strategy for biodiversity conservation.[2] Doing so is expected to enhance resilience to climate change by helping species undergo adaptive range shifts, while also reducing existing stresses associated with habitat fragmentation.[3]

Despite recognition of connectivity enhancement's value as an adaptation strategy, little work has been done to translate this broad recommendation into specific, on-the-ground actions for connectivity conservation in a changing climate. Effectively managing habitat connectivity to promote biological resilience requires knowledge about how climate change may impact connectivity, what additional connectivity needs species may have as they undergo range shifts, and what actions can be taken to address these impacts and needs.

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1. Chen, I.C., Hill, J.K., Ohlemuller, R., Roy, D.B., and C.D. Thomas. 2011. Rapid range shifts of species associated with high levels of climate warming. *Science* 333:1024-1026
2. Heller, N. E., and E. S. Zavaleta. 2009. Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation* 142:14-32.
3. Krosby, M., Tewksbury, J., Haddad, N., and J. Hoekstra. 2010. Ecological connectivity for a changing climate. *Conservation Biology* 24:1686-1689.

The Washington-British Columbia Transboundary Climate-Connectivity Project was initiated to promote effective habitat connectivity management under climate change by addressing two primary challenges: the significant gap between climate and connectivity science and practice; and the analytical, political, and physical barriers to connectivity presented by political borders. The transboundary region of Washington, USA, and British Columbia, Canada (Fig. 1), is an oft-neglected geography among the priority regions of conservation groups and government agencies, yet maintaining its permeability to wildlife movement will be vital to maintaining regional resilience to climate change. Previous work by the Washington Wildlife Habitat Connectivity Working Group (WHCWG) engaged transboundary stakeholders in identifying information needs for managing habitat connectivity in a changing climate.[4] The primary finding of this effort was that no single existing climate or connectivity model output or synthesis of existing model outputs could best inform connectivity conservation under climate change, as any model's usefulness would depend upon the connectivity management goals and activities of the user. But more strikingly, transboundary stakeholders – including land and wildlife managers from government agencies, tribes, and NGOs – made it clear that they did not have the capacity to apply climate-related models to their decision-making. This suggested that the most urgent need was not the creation of new models to guide connectivity management in a changing climate, but rather a concerted effort to translate existing model outputs to meet the information needs of practitioners, and to build practitioners' own capacity to access, interpret, and apply climate-related model outputs to their connectivity management efforts.

Building this capacity by assisting practitioners in identifying climate impacts and adaptation actions for transboundary habitat connectivity would promote many regional and national conservation priorities. Regionally, priorities of the Great Northern and North Pacific Landscape Conservation Cooperatives (GNLCC and NPLCC, respectively) include assessing the implications of climate change for the maintenance of large, intact, permeable landscapes; and facilitating collaboration, adaptation capacity-building, and use of traditional ecological knowledge to inform stakeholder decisions. Habitat connectivity is one of four priority issues of the GNLCC's Cascadia Partner Forum, whose mission is to build the adaptive capacity of Cascadia landscapes. Addressing these challenges also meets multiple strategic needs of the Northwest Climate Science Center, particularly the need to improve our understanding of climate threats to habitat connectivity and potential for fragmentation of terrestrial habitats. At a broader scale, identifying and protecting wildlife corridors are primary goals of the Western Governors' Association's Wildlife Corridor Initiative, and connectivity enhancement is a priority climate change adaptation strategy for the US National Park Service, US Forest Service, and US Fish & Wildlife Service. It is similarly recognized as a priority strategy by provincial and federal ministries in British Columbia and Canada, respectively.

The Washington-British Columbia Transboundary Climate-Connectivity Project thus convened

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4. WHCWG (Washington Wildlife Habitat Connectivity Working Group). 2013. Washington Connected Landscapes Project: British Columbia–Washington Transboundary Habitat Connectivity Scoping Report. Washington Departments of Fish and Wildlife, and Transportation, Olympia, WA.

scientist-practitioner partnerships aimed at promoting capacity- and community-of-practice building among transboundary land and wildlife managers tasked with maintaining connected, resilient landscapes in a changing climate. **The objective of these partnerships was to produce partnership-specific plans for managing habitat connectivity under climate change,** by:

1) Identifying partner-specific goals and objectives for habitat connectivity management
2) Determining how climate change is likely to impact these goals and objectives, and
3) Developing strategies and tactics for addressing these impacts.

## 5. ORGANIZATION AND APPROACH

We convened three scientist-practitioner partnerships reflecting a range of management goals, activities, and scales related to habitat connectivity. The project area spanned the transboundary region of Washington State, USA, and British Columbia, Canada, with partnerships established at three spatial scales (Fig. 1):

- **The Washington-British Columbia Transboundary Region**. Partners included the US Forest Service; US National Park Service; BC Parks; and BC Ministry of Forests, Lands, and Natural Resource Operations
- **The Okanagan-Kettle Region**: Partners included the Transboundary Connectivity Group (i.e., WHCWG and its BC partners).
- **Okanagan Nation Territory**: Partners included the Okanagan Nation Alliance and its member bands and tribes, including the Colville Confederated Tribes.

For all partnerships, science partners included the Climate Impacts Group at the University of Washington and the Pacific Climate Impacts Consortium at the University of Victoria. Together, the science-practitioner partnerships engaged in a collaborative, iterative assessment of climate impact and adaptation actions for transboundary habitat connectivity. This co-productive assessment process was designed to promote capacity- and community-of-practice building among practitioner partners while ensuring that project products were directly relevant and immediately applicable to practitioners' decision-making.

The assessment approach outlined in our original project design consisted of identifying partner-specific goals and objectives for habitat connectivity management, determining how climate change is likely to impact these goals and objectives, and developing adaptation actions for addressing these impacts. However, as described below, project partners ultimately modified this plan in response to the opportunities and constraints presented by a large, transboundary, inter-institutional project. The final assessment approach entailed: i) focusing the assessment on a suite of case studies, including numerous species, a vegetation system, and a region; ii) identifying potential climate impacts on habitat connectivity for each case study; and iii) developing partner-specific actions for addressing these impacts.

Project partners engaged in a series of initial workshops and phone calls to introduce practitioner partners to the project, develop and build buy-in around the assessment approach, and gain a shared understanding of practitioner partners' goals and objectives for connectivity management. While the original project design called for a single initial workshop, difficulty arranging international travel for practitioner partners (particularly US federal employees) made it impossible to convene all partners simultaneously at the start of the project. We therefore held a series of smaller workshops and phone calls arranged at practitioner partners' convenience, to encourage participation by those unable to travel across the border.
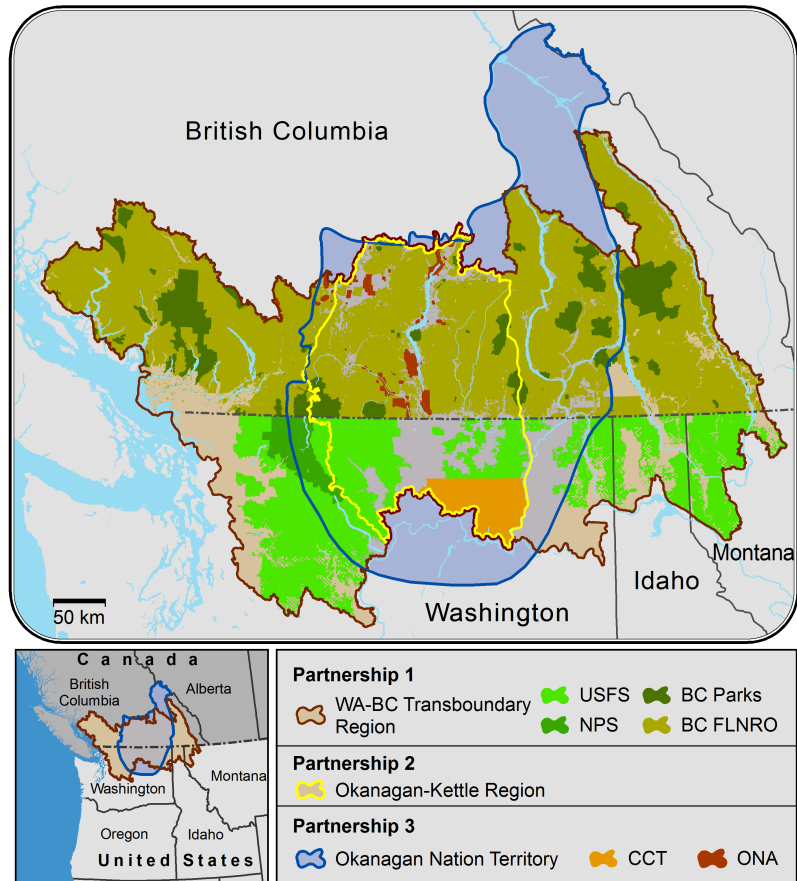


**Figure 1. Project area and partnerships**: 1) At the scale of the Washington-British Columbia transboundary region: US Forest Service (USFS); National Park Service (NPS); BC Parks; and BC Ministry of Forests, Lands, and Natural Resource Operations (BC FLNRO); 2) At the scale of the Okanagan-Kettle Region: the Transboundary Connectivity Working Group (i.e., the WHCWG and its BC partners); and 3) At the local and regional scale of First Nations reserves and tribal reservation lands within the Okanagan Nation Territory: the Okanagan Nation Alliance (ONA) and its member bands and tribes, including the Colville Confederated Tribes (CCT).

The information gathered at these initial workshops and phone calls provided scientist partners with an understanding of the connectivity- and climate-related management goals, activities, and capacities of practitioner partners. It also revealed a strong need to focus the work of the partnerships around a limited number of specific connectivity conservation targets. Addressing the extensive and diverse connectivity and climate-related information needs of each individual partner was well beyond the project's capacity, and would not have contributed to the project's goal of promoting a transboundary community-of-practice via partner collaboration.

Scientist and practitioner partners thus collectively agreed to focus their assessment on a suite of transboundary case studies spanning a range of ecological scales, including numerous individual species, a vegetation system, and a region (Table 1). The case study species, system, and region were not intended to act as connectivity conservation umbrellas for the

**Table 1. Case study species, vegetation system, and region**

| Species | |
|---|---|
| **Common Name** | **Scientific Name** |
| Wolverine | *Gulo gulo* |
| Mountain goat | *Oreamnos americanus* |
| White-tailed ptarmigan | *Lagopus leucura* |
| Whitebark pine | *Pinus albicaulis* |
| Canada lynx | *Lynx canadensis* |
| American marten | *Martes caurina* |
| Black bear | *Ursus americanus* |
| Mule deer | *Odocoileus hemionus* |
| Lewis's woodpecker | *Melanerpes lewis* |
| Tiger salamander | *Ambystoma tigrinum* |
| Bull trout | *Salvelinus confluentus* |
| **Vegetation System** | |
| Shrub-Steppe | |
| **Region** | |
| Okanagan-Kettle Region | |

transboundary region's broader biota, as the individualistic nature of species' responses to climate change precludes traditional umbrella approaches to conservation planning. Rather, they were selected based on their shared priority status among project partners, representation of diverse habitat types and climate sensitivities, and data availability. These selection criteria were chosen to promote transboundary and inter-institutional collaboration around shared conservation priorities, while giving partners the opportunity to explore a range of climate and movement sensitivities, relevant datasets, and adaptation actions.

*ii. Identifying potential climate impacts on habitat connectivity for case study species, vegetation system, and region*

To identify potential climate impacts on transboundary habitat connectivity, project partners created conceptual models that identified the key landscape features and processes expected to influence habitat connectivity for each case study species and system, which of those are expected to be influenced by climate, and how. Simplifying complex ecological systems in such a way can make it easier to identify specific climate impacts and adaptation actions. For this reason, conceptual models have been promoted as useful adaptation tools, and have been applied in a variety of other systems.[5] Conceptual models prepared by project partners were based on participant expertise; peer-reviewed articles and reports; and, when possible, review by species, vegetation system, and regional experts. That said, these models were intentionally simplified and not intended to represent comprehensive assessments of the full suite of landscape features and processes contributing to habitat connectivity.

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5. Cross, M.S., et al. 2012. The Adaptation for Conservation Targets (ACT) framework: a tool for incorporating climate change into natural resource management. *Environmental Management* 50:341–351.

Project participants used conceptual models together with models of projected future changes in species distributions, vegetation communities, and relevant climate variables to identify potential impacts on habitat connectivity for each case study. Partners did this by evaluating projected future changes for each climate variable included in the model, and how these changes were likely to affect the landscape features and processes important to habitat connectivity. Because a key project goal was to increase practitioner partners' capacity to access, interpret, and apply existing climate and connectivity model outputs to their decision-making, we relied on a few primary datasets that are freely available, span all or part of the transboundary region, and reflect the expertise of project scientist partners. These sources included habitat connectivity models produced by the Washington Connected Landscapes Project,[6] future climate projections produced by the Integrated Scenarios of the Future Northwest[7] and the Pacific Climate Impacts Consortium's Regional Analysis Tool[8], and models of projected range shifts and vegetation change produced by the Pacific Northwest Climate Change Vulnerability Assessment.[9]

*iii. Developing partner-specific actions for addressing potential climate impacts on case study species, vegetation systems, and regions*

After identifying potential climate impacts on habitat connectivity, project participants used conceptual models to identify which relevant landscape features or processes could be affected by management activities, and subsequently what actions could be taken to address projected climate impacts for each species (Fig. 3). Partners did this by considering the management activities identified in the conceptual models, and how specific activities could address potential climate impacts on landscape features or processes important to habitat connectivity. Adaptation actions identified by this approach addressed several distinct categories of impacts and responses, including potential climate impacts on habitat connectivity, novel habitat connectivity needs for promoting climate-induced shifts in species distributions, and spatial priorities for implementation.

It should be noted that one partnership did not use a conceptual model approach, because their connectivity goals and objectives were specific and simple enough that it was not required. The Transboundary Connectivity Group's goal was to identify potential climate impacts and adaptation actions for heavily fragmented valley floors within the Okanagan-Kettle region (Fig. 1), with an emphasis on connectivity priority areas they had identified in a recent assessment.[10] Participants in this partnership reviewed projected changes in vegetation and

6. Washington Wildlife Habitat Connectivity Working Group. 2011. Washington Connected Landscapes Project: Climate gradient corridors report. Washington Departments of Fish and Wildlife, and Transportation. Olympia, WA. www.waconnected.org.
7. Integrated Scenarios of the Future Northwest Environment. http://climate.nkn.uidaho.edu/IntegratedScenarios
8. Pacific Climate Impacts Consortium (PCIC), Regional Analysis Tool. 2014. https://www.pacificclimate.org/analysis-tools/regional-analysis-tool
9. Pacific Northwest Climate Change Vulnerability Assessment (PNWCCVA). http://www.climatevulnerability.org/
10. Transboundary Connectivity Group. 2016. Providing a Regional Connectivity Perspective to Local Connectivity Conservation Decisions in the British Columbia–Washington Transboundary Region: Okanagan-Kettle Subregion Connectivity Assessment. Available at: http://waconnected.org.

relevant climatic variables to identify potential impacts on these valley floors and priority connectivity areas, and then developed actions for addressing these impacts and promoting species range shifts as the climate warms.

## 6. PROJECT RESULTS

Project partners identified a wide range of potential climate impacts on habitat connectivity and a similarly diverse set of adaptation responses. A summary list of key climate impacts and adaptation actions for each case study species, vegetation system, and region can be found in Table 2, and a list of the datasets used to identify potential climate impacts for each case study can be found in Table 3.

In many ways, the key climate impacts identified for case studies were similar to what would be found in a climate change vulnerability assessment for Northwest species and ecosystems (e.g., declining snowpack, warming stream temperatures, increasing risk of wildfire). What distinguished this assessment was its focus on how these impacts would affect habitat connectivity: would projected changes in climatic variables make existing core habitat areas and dispersal corridors more or less permeable to wildlife movement? Would projected changes in areas of climatic suitability result in core habitat areas becoming more or less fragmented or isolated, or would they require a species to significantly modify its range to reach new areas of climatic suitability? Similarly, many response actions resembled what would be found in a regional adaptation plan (e.g., use prescribed burns to reduce risk of large wildfires), but were focused on maintaining habitat connectivity in the face of change (e.g., implement prescribed burns to maintain the quality of existing core habitat areas and corridors) and providing the types of habitat connectivity required to accommodate species range shifts (e.g., protect additional corridors that fall along climatic gradients).

Project products were designed in collaboration with practitioner partners to ensure their relevance and ease of application to decision-making. These products include:

- **A project overview report**, which describes the project's rationale, partnerships, approach, and key findings.
- **Additional reports describing key findings for each case study species, vegetation system, and region**. These reports are provided as appendices to the overview report, and are intended to act as stand-alone resources. They include summary descriptions of the project and assessment process, key climate impacts and adaptation actions for each case study; and all materials used to identify potential climate impacts and adaptation actions for each case study (e.g., conceptual models, habitat connectivity models, and models of projected future changes in species distributions, vegetation communities, and climate variables).
- **An interactive project gallery on the online mapping platform Data Basin**. This project gallery includes all project reports and associated assessment materials, including interactive and downloadable connectivity and climate datasets (Table 3). This gallery can be found at:
  https://nplcc.databasin.org/galleries/5a3a424b36ba4b63b10b8170ea0c915e

# Table 2. Key climate impacts and adaptation actions for each case study.

## I. Addressing Climate Impacts on Habitat Connectivity — Case Study

| Climate impact(s) addressed | ADAPTATION ACTION | Wolverine | Mountain Goat | White-tailed Ptarmigan | Whitebark Pine | Canada Lynx | American Marten | Black Bear | Mule Deer | Lewis's Woodpecker | Tiger Salamander | Bull Trout | Shrub-Steppe | Okanagan-Kettle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Increasing risk of wildfire | Using prescribed burns, thinning, and targeted fuel reduction to reduce the risk of catastrophic wildfires. | x |  |  | x | x | x | x | x | x |  | x | x | x |
|  | Incorporating projections and observations of climatic changes (e.g., earlier onset of fire season) to inform the timing of fire prevention techniques as conditions change, in order to maximize safety and effectiveness |  |  |  |  | x | x | x | x | x |  |  | x | x |
|  | Using some degree of fire suppression in cool, moist forests with long fire return intervals. |  |  |  |  | x | x |  |  |  |  |  |  |  |
|  | Referencing the forest and grazing practices of tribes and First Nations to identify traditional strategies for managing fire risk. |  |  |  |  | x |  |  | x | x |  |  | x | x |
| Decreasing snowpack depth and duration | Increasing snow depth locally (e.g., via snow fences), recognizing that local-scale snow management is unlikely to have a significant impact on habitat connectivity. Therefore, prioritize such efforts within important core habitat areas and corridors. | x |  |  |  | x | x |  |  |  |  |  |  |  |
|  | Ensuring that snowpack retention practices are compatible with other forest management practices that balance the need for fire and natural resource management with the need for sufficient horizontal cover. |  |  |  |  | x | x |  |  |  |  |  |  |  |
|  | Identifying and prioritizing areas where deep spring snowpack is most likely to persist in the future (e.g., north-facing slops and canyons). | x |  |  |  | x | x |  |  |  |  |  |  |  |
| Changes in vegetation | Monitoring and responding to changes in vegetation (e.g., shifts in tree line, transition of shrub-steppe to other vegetation types, loss of forested corridors in low elevation valleys) that may affect habitat connectivity. Consider use of LIDAR remote sensing and other technologies yielding high resolution data. | x | x | x | x | x |  | x |  |  | x |  | x | x |
|  | Minimizing forest (or non-target tree) encroachment in key core habitat areas and corridors by mechanically removing invading trees or using prescribed burns to reduce tree recruitment. |  |  |  | x | x |  |  |  |  |  |  | x |  |
|  | Developing planting plans that evaluate and potentially include genotypes adapted to projected future climatic conditions |  |  |  | x |  |  |  |  |  |  |  | x |  |
| Changes in invasive species | Incorporate invasive species management into all activities related to habitat connectivity conservation. |  |  |  |  |  |  |  |  |  |  |  | x | x |
|  | In areas heavily invaded by cheatgrass, considering prescribed burning in combination with herbicide and native plant reseeding. |  |  |  |  |  |  |  |  |  |  |  | x | x |
| Changes in seed dispersal | Identifying and protecting stands that are large enough to attract seed dispersers and serve as a seed source |  |  |  | x |  |  |  |  |  |  |  |  |  |
|  | Identifying and protecting stands that could serve as links or stepping stones for seed dispersers moving among larger stands |  |  |  | x |  |  |  |  |  |  |  |  |  |
| Increasing stream temperatures | Restoring riparian vegetation, which will help shade streams and reduce stream temperatures. |  |  |  |  |  |  |  |  |  |  | x |  | x |
|  | Excluding cattle from riparian areas to prevent loss of vegetative cover. |  |  |  |  |  |  |  |  |  | x | x |  |  |
|  | Investigate the feasibility and benefit of manually transporting fish around thermal barriers in streams. |  |  |  |  |  |  |  |  |  |  | x |  |  |
| Decreasing summer streamflows | Managing forests to maximize groundwater infiltration. |  |  |  |  |  |  |  |  |  |  | x |  |  |
|  | Using dam release events to maintain water levels and stream temperatures adequate for fish passage. |  |  |  |  |  |  |  |  |  |  | x |  |  |
|  | Identifying and mitigating barriers such as dams or poorly designed road crossings or culverts to promote fish passage. |  |  |  |  |  |  |  |  |  |  | x |  |  |

| Climate impact(s) addressed | ADAPTATION ACTION | Wolverine | Mountain Goat | White-tailed Ptarmigan | Whitebark Pine | Canada Lynx | American Marten | Black Bear | Mule Deer | Lewis's Woodpecker | Tiger Salamander | Bull Trout | Shrub-Steppe | Okanagan-Kettle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Declining water availability and quality for ponds/wetlands | Restoring and/or protecting riparian vegetation to shade ponds, which would reduce water temperatures and evaporation rates. |  |  |  |  |  |  |  |  |  | x |  |  | x |
|  | Excluding cattle from ponds and surrounding vegetation (e.g., by installing fencing), and using techniques (e.g., fabric and gravel installation) to prevent cattle from leaving pockmarks, which reduce pond quality. |  |  |  |  |  |  |  |  |  | x |  |  | x |
|  | Protecting and/or reintroducing beavers into watersheds, which may improve wetland quality and connectivity. |  |  |  |  |  |  |  | x |  | x |  |  | x |
|  | Widening ponds to increase access for salamanders and/or deepening ponds to increase pond persistence into summer. |  |  |  |  |  |  |  |  |  | x |  |  | x |
|  | Adding water and removing predatory fish from key ponds (highly resource intensive; an emergency measure). |  |  |  |  |  |  |  |  |  | x |  |  | x |
|  | If frost seal does not occur often enough to maintain spring wetlands, considering artificially irrigating key wetlands. |  |  |  |  |  |  |  | x |  | x |  |  |  |
|  | Establishing retention ponds in urban areas, and treating them as managed wetlands. |  |  |  |  |  |  |  |  |  | x |  |  | x |
|  | Diverting rainwater into existing ponds (while addressing potential for chemical run-off and turbidity issues). |  |  |  |  |  |  |  |  |  | x |  |  | x |
| Changes in the timing, location, and intensity of human activities | Managing access in core habitat areas and corridors (especially those projected to maintain climatic suitability) to reduce impacts from recreation, grazing, and other uses. |  | x | x |  | x | x | x |  |  |  |  | x |  |
|  | Monitoring changes in the timing and intensity of recreation and other activities, particularly within core habitat areas and movement corridors. | x |  |  |  |  | x | x |  |  |  |  |  |  |

## II. Enhancing Connectivity to Facilitate Range Shifts — Case Study

| Climate impact(s) addressed | ADAPTATION ACTION | Wolverine | Mountain Goat | White-tailed Ptarmigan | Whitebark Pine | Canada Lynx | American Marten | Black Bear | Mule Deer | Lewis's Woodpecker | Tiger Salamander | Bull Trout | Shrub-Steppe | Okanagan-Kettle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Geographic shifts in species ranges | Maintaining and restoring corridors between areas of declining climatic suitability and areas of stability or increasing suitability. | x | x |  |  | x | x | x |  | x | x |  | x |  |
|  | Evaluating the risks and benefits of manually transporting species to areas of projected stable or increasing climatic suitability. |  |  | x | x |  |  |  |  |  |  | x |  |  |
|  | Maintaining and restoring corridors that span elevation gradients (e.g., climate gradient corridors), to ensure that species have the ability to disperse into cooler habitats as the climate warms. | x | x | x | x | x | x | x | x | x | x | x | x | x |
|  | Maintaining and restoring riparian areas, which span climatic gradients and are used as movement corridors by many species. |  |  |  |  |  | x | x | x | x | x |  |  | x |
|  | Planning the placement, orientation, and shape of reserve patches to maximize connectivity, span climatic gradients, and cross low-elevation valleys. |  |  |  |  |  | x | x | x |  |  |  |  |  |

## III. Spatial Priorities for Implementation | Case Study

| TOPIC ADDRESSED | SPATIAL PRIORITY | Wolverine | Mountain Goat | White-tailed Ptarmigan | Whitebark Pine | Canada Lynx | American Marten | Black Bear | Mule Deer | Lewis's Woodpecker | Tiger Salamander | Bull Trout | Shrub-Steppe | Okanagan-Kettle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Spatial Priorities for Implementation** | Existing core habitat areas and corridors, which will be important for maintaining populations under current climate, and facilitating species response to future change. Pinch-points, barriers and restoration opportunities, and areas of high network centrality all offer potential priority areas for implementation. | | | | | x | x | | | x | x | x | | |
| | Climate-gradient corridors, which may facilitate species dispersal into cooler habitats as climate warms. | x | | x | x | x | x | x | | x | | | x | x |
| | Climate-resilient core habit areas and corridors (i.e., those that are projected to remain climatically suitable). | | | x | x | x | x | x | | x | x | x | | x |
| | Riparian areas, which currently act as species movement corridors, and also span climatic gradients, facilitating dispersal into cooler habitats. | | | | | x | x | x | | x | | | | |
| | Cold-water refuges – areas within streams that have persistently lower temperatures than other stream areas | | | | | | | | | | | x | | |
| | Ponds that are deep, free of predatory fish, and located in cooler and/or wetter micro-climates. | | | | | | | | | | x | | | x |
| | Highways, especially those that run along low-elevation valleys (e.g., Highway 97 and 3A) and those that cross the Cascade Range (e.g., Highway 3 and Interstate 90), which may present barriers to climate-driven range shifts. | x | x | | | x | x | x | x | | | | | |
| | Low elevation valleys, particularly the Fraser River Valley and the Okanagan Valley. Connectivity Focus Areas offer key areas for implementation in the Okanagan Valley. | x | x | | | x | | x | x | x | x | | x | x |

## III. Policy Considerations | Case Study

| TOPIC ADDRESSED | ADAPTATION ACTION | Wolverine | Mountain Goat | White-tailed Ptarmigan | Whitebark Pine | Canada Lynx | American Marten | Black Bear | Mule Deer | Lewis's Woodpecker | Tiger Salamander | Bull Trout | Shrub-Steppe | Okanagan-Kettle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **First Nations and tribal referrals response processes** | Encouraging the use of highways design techniques that preserve connectivity (e.g., overpasses, open span bridges, culverts). | | | | | x | | x | x | | | | | |
| | Encouraging the incorporation of wildlife-friendly fencing into permitting and planning processes. | | | | | x | | x | x | | | | | |
| | Considering impacts and opportunities for habitat connectivity during the referrals process. | | | | | | | | | | | | x | |
| | Evaluating opportunities to reduce grazing pressure in key corridors. | | | | | | | | | | | | x | |
| **Laws and regulations** | Monitoring core habitats and movement corridors for suitability and being prepared to address and/or modify the legal context for management (e.g., Endangered Species Act). | | | | x | x | | | | | x | | | |
| | Considering timing tribal/First Nation hunting seasons around key dispersal periods and/or lowering take limits to reduce pressure on populations. | | | | | | | x | x | | | | | |

| TOPIC ADDRESSED | ADAPTATION ACTION | Wolverine | Mountain Goat | White-tailed Ptarmigan | Whitebark Pine | Canada Lynx | American Marten | Black Bear | Mule Deer | Lewis's Woodpecker | Tiger Salamander | Bull Trout | Shrub-Steppe | Okanagan-Kettle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Land and water use planning and management** | Limiting the development of forestry activities at high elevations (particularly those likely to remain climatically suitable). | | | | x | | | | | | | | | |
| | Managing forestry activities to ensure that forest canopy cover remains continuous throughout corridors for montane forest species, and that large trees, old snags, and tree cavities remain present. | | | | | x | x | | | | | | | |
| | Reviewing and implementing existing guidance and plans relating to species habitat management, modifying to address climate. | x | | | | x | x | x | x | | x | x | | x |
| | Investigating whether having multiple priority species affected in the same area could lead to greater pressure to change management practices if cumulative impacts can be demonstrated. | x | x | | | x | x | x | | | | | | |
| | Coordinating stewardship and management activities with governments, NGOs, tribes and First Nations, and private landowners. | x | | | x | | | x | x | x | x | | x | |
| | Placing limitations on proposals so that they enhance conservation measures (e.g., require buffers). | | | | | | | | | | | | | |
| | Striving for community design that limit fragmentation of habitat and include habitat corridors. | | | | | x | | x | | | | | | |
| | Identifying and protecting wetlands and other water sources in valleys. These may help to promote movement of montane forest species through dry, low-elevation valleys, while also promoting core habitat area and corridor quality for low-elevation species. | | | | | | | x | x | x | | | | x |
| | Securing water rights to maintain moisture in riparian areas and wetlands that provide core habitat and movement corridors. | | | | | | | x | x | x | x | x | | x |
| | Carefully reviewing water permit requests for new irrigation withdrawals to ensure that key ponds, wetlands, and water resources remain available within core habitat areas and dispersal corridors. | | | | | | | | | | x | | x | |
| | Monitoring trends and reviewing policies relating to vineyard establishment. Strive to avoid establishing vineyards in shrub-steppe core habitat areas or corridors. | | | | | | | | | | | | x | |
| | Considering establishment of additional conservation areas at elevations above current species ranges to protect future habitats. | | | | | | | | | | | | x | |
| | Using large parcel zoning to maintain contiguity of natural areas within First Nation and tribal lands. Outside of these lands, work with private landowners and environmental policy to maintain contiguous swaths of suitable land that will facilitate movement. Consider full range of approaches, from land purchases and easements to stewardship activities. | | | | | x | | x | x | | | | x | |
| **Transportation Planning** | Coordinating with transportation agencies to evaluate appropriate management responses to potential changes in seasonal road openings and closings as snow conditions change and higher elevation habitats potentially become more accessible to people. | x | x | | | | x | x | | | | | | |
| | Coordinating with transportation agencies to ensure that new roads do not negatively impact priority areas for habitat connectivity under climate change (e.g., climate-gradient corridors, or climate-resilient core habitat areas and corridors). | x | x | | | x | x | x | x | | x | x | | x |
| | Coordinating with transportation agencies to mitigate barrier effects of roads crossing priority areas for habitat connectivity under climate change (e.g., by incorporating crossing structures into road design, or retro-fitting roads with crossing structures). | | | | | | | x | | | x | | | |

| IV. Research Needs | | Case Study | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TOPIC ADDRESSED** | **ADAPTATION ACTION** | Wolverine | Mountain Goat | White-tailed Ptarmigan | Whitebark Pine | Canada Lynx | American Marten | Black Bear | Mule Deer | Lewis's Woodpecker | Tiger Salamander | Bull Trout | Shrub-Steppe | Okanagan-Kettle |
| **Research needs** | Developing transboundary habitat connectivity models. | | | x | | | | | | | x | | | |
| | Gathering additional empirical information on species movement to validate and improve corridor models, and understand what landscape features facilitate or hinder movement. | | x | x | x | x | x | | | x | | x | | |
| | Mapping current population locations (as opposed to general range boundaries). | | | x | x | x | | | | | | | | |
| | Incorporating projected changes in human land use into habitat connectivity models. | | | | | | | | | | | | | x |
| | Developing fine-scale, transboundary models of riparian location and condition. | | | | | x | x | x | x | x | | | | |
| | Developing transboundary models of wildfire risk and probability of pest outbreaks. | | x | x | | x | x | x | x | x | | x | x | |
| | Developing climatic niche models. | | x | x | | | | | | | | | x | |
| | Evaluating the extent to which areas projected to become climatically suitable for species include suitable non-climatic conditions (e.g., soils, vegetation, aquatic habitat). | | | | | | | | | | x | | x | |
| | Identifying climate-resilient core habitat areas and corridors (i.e., those likely to maintain climatic suitability, and experience relatively modest changes in relevant climatic variables). | x | x | x | x | x | x | x | | | x | x | x | |
| | Identifying potential climate impacts on specific existing core habitat areas and corridors. | x | x | | | x | x | x | | | x | | | |
| | Identifying corridors between locations with projected declines in climatic suitability and areas with projected stable or increasing climatic suitability. | x | x | | | x | x | x | | | x | x | | |
| | Developing transboundary models of cold-water refuges and projected future bull trout distributions. | | | | | | | | | | | x | | |
| | Developing transboundary aquatic habitat connectivity models (including identification of significant barriers to movement). | | | | | | | | | | | x | | |

## 7. ANALYSIS AND FINDINGS

This project demonstrated the effectiveness of scientist-practitioner partnerships to build capacity and a community-of-practice for decision-makers, while simultaneously producing useful products for guiding habitat connectivity management in a changing climate.

## 8. CONCLUSIONS AND RECOMMENDATIONS

Our experience working across borders with diverse partners to incorporate climate change into habitat connectivity management yielded several valuable lessons. In particular, we felt that the success of the project had much to do with our adoption of a case study and conceptual model approach, and our ability to respond creatively and flexibly as transboundary and institutional barriers were encountered.

*i. Use of case study species, vegetation system, and region*

Employing a case study approach was not in our original project design, yet doing so proved critical to the project's success, for several reasons. First, focusing assessments on shared conservation priorities was key to meeting the project goal of promoting collaboration and a community-of-practice among disparate transboundary and inter-institutional partners. A case study approach was also more logistically and analytically efficient than focusing on each individual partners' information needs, making the most of the project's limited capacity. Focusing on specific case studies also helped facilitate the translation of a high-level adaptation strategy (connectivity conservation) into specific, concrete actions. Finally, our assessment of case studies at a range of ecological scales – from individual species, to a vegetation system, to a geographic region – demonstrated the transferability of this approach to diverse connectivity conservation targets.

**Table 3. Datasets used to identify potential climate impacts for each case study.**

| DATASETS USED IN ASSESSMENT | Wolverine | Mountain Goat | White-tailed Ptarmigan | Whitebark Pine | Canada Lynx | American Marten | Black Bear | Mule Deer | Lewis's Woodpecker | Tiger Salamander | Bull Trout | Shrub-Steppe | Okanagan-Kettle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **I. Habitat connectivity models** | | | | | | | | | | | | | |
| Species Corridor Network | x | x | | | x | x | x | x | | x | | | |
| Landscape Integrity Corridor Network | | | x | x | | | | | | x | x | x | |
| Climate-Gradient Corridor Network | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Connectivity Focus Areas | | | | | | | | | | | | | x |
| **II. Projected changes in species distributions** | | | | | | | | | | | | | |
| Climatic Niche Model | x | | | x | x | x | x | x | x | x | | x | x |
| Cold Water Climate Shield | | | | | | | | | | | x | | |
| **III. Projected changes in vegetation communities** | | | | | | | | | | | | | |
| Climatic Niche Vegetation Model | x | x | x | | x | x | x | | | | | | x |
| Mechanistic Vegetation Model | x | x | x | | x | x | x | | | | | | x |
| **IV. Projected changes in insect survival** | | | | | | | | | | | | | |
| Mountain Pine Beetle Survival | x | | | x | x | x | x | x | x | | | | |
| **V. Projected changes in climatic variables** | | | | | | | | | | | | | |
| Spring (April 1) Snowpack | x | x | x | x | x | x | x | | x | x | x | x | |
| Late Spring (May 1) Snowpack | | | | | | x | | | | | | | |
| Length of Snow Season | x | x | x | x | x | x | x | x | | | | | |
| Percentage of Winter Precipitation Captured in April 1st Snowpack | | | | | x | | | x | | | | | |
| Number of Frost Days | | | | | | | | | | | | x | x |
| Growing Season Length | | | | | | x | | | | | | | |
| Increase in Average Annual Daytime Temperature | | | x | | | | | | | x | | | |
| Total Spring Precipitation | | | x | | | | | | | x | x | x | x |
| Total Summer Precipitation | | | | | | | | x | | | x | | x |
| Annual Maximum 24-hour Precipitation | | | | | | | | | | | x | | |
| Number of Heavy Precipitation Days | | | | | | x | | | | | | | x |
| Average Precipitation Intensity | | | | | | x | | | | | | | x |
| Total Spring Runoff | | | | | | | | | | x | x | | x |
| Total Summer Runoff | | | | | | | | | | x | x | | x |
| Evapotranspiration, July-September | | | | | | | | x | | | x | | x |
| Evapotranspiration, March-May | | | | | | | | | | | x | | x |
| Potential Evapotranspiration, July-September | | | | | | | | | | x | | | |
| Dry Spell Duration | | | | | x | | x | x | x | | x | x | |
| Water Deficit, July-September | x | x | | x | | | x | x | | | x | | x |
| Soil Moisture, July-September | | x | | x | | x | x | x | x | x | | x | x |
| Days with High Fire Risk | x | x | x | x | x | x | x | x | x | | x | x | x |
| Stream Temperature | | | | | | | | | | | x | | |

## ii. Taking a conceptual model approach

Much like our use of case studies, taking a conceptual model approach was not in our original project design, but proved key to the project's success. In particular, conceptual models were vital to overcoming the challenge of translating a high-level adaptation strategy into specific, on-the-ground actions. By simplifying the abstract concept of habitat connectivity into its key physical components for each case study, both scientist and practitioner partners were better able to consider which landscape features and processes contributing to habitat connectivity

were likely to be influenced by climate, how specific climate datasets could be used to identify potential climate impacts, and how habitat connectivity model outputs and other datasets could help practitioners identify where and how they could intervene to address those impacts. In short, the conceptual model approach made an initially vague task (i.e., adapt connectivity management to climate change) concrete and tractable, and yielded specific, useful results.

### iii. Employing creativity and flexibility in addressing project barriers

We found that creativity, flexibility, and persistence were key to overcoming the significant barriers presented by a large, transboundary project with diverse partners. For example, travel to workshops turned out to be a significant barrier to practitioner partner involvement, particularly for US federal employees needing to cross the border into Canada. We responded by supplementing the initial workshop with numerous smaller calls and meetings held at practitioner's offices, and by ultimately convening an additional workshop at Peace Arch Park at the Interstate 5 border crossing between Washington and British Columbia; entrance to international peace parks does not require a passport from either Americans or Canadians, circumventing institutional restrictions around international travel. Creativity and flexibility were also vital to accommodating the varying levels of engagement possible among practitioner partners. While some practitioner partners were able to participate steadily throughout the project, many individuals flowed in and out over the course of the project, or were only able to participate to lesser degrees (e.g., attending webinars but not workshops). Providing frequent and diverse opportunities for engagement and encouraging individuals to participate when and how they were able undoubtedly contributed to a higher level of practitioner participation than if we had strictly adhered to the limited opportunities included in the original project design. That said, this approach required significantly more time and resources – particularly for scientist partners – than the original plan of convening a total of two workshops and four webinars.

We also identified several remaining needs and next steps for promoting climate-informed, transboundary habitat connectivity management, including:

### i. Future research needs

Case study assessments revealed several areas where future research could help improve practitioners' ability to identify and address climate impacts on habitat connectivity. Most importantly, assessments revealed a significant need for the development of transboundary models of both habitat connectivity (which were unavailable for many species) and projected changes in climate variables (e.g., snow pack, risk of wildfire and insect outbreaks). Assessments also indicated a need for additional empirical research on wildlife movement and range shifts, both to validate existing habitat connectivity and range shift models and to inform the development of new models. Finally, assessments showed that additional research is needed to improve the spatial specificity of climate impacts on habitat connectivity and priority areas for adaptation actions, from simple GIS overlays of climate impacts and existing connectivity models, to sophisticated modeling identifying potential corridors between current and future areas of climatic suitability.

*ii. Need for ongoing capacity-building*

Feedback from practitioner partners suggests that there is significant need for and interest in ongoing efforts to build practitioners' capacity to access, interpret, and apply climate and connectivity models to their decision-making. Hands-on, experiential learning in the context of co-productive, scientist-practitioner partnerships is particularly effective at building such capacity; however, such efforts are time- and resource-intensive for both scientists and practitioners. Future innovation and investment in scaling-up such capacity-building (e.g., ongoing workshops, webinars, and trainings or large-scale co-production efforts) are greatly needed.

*iii. Need for continued transboundary engagement*

Effectively managing habitat connectivity in a changing climate will require ongoing transboundary engagement of scientists and practitioners to ensure that land and wildlife management is coordinated across the border and informed by the best available science. While numerous mechanisms are in place to ensure coordinated management of transboundary aquatic species and resources, few frameworks exist for promoting such engagement around terrestrial species and systems. There is also need for additional funding streams specifically directed toward collaborative research among transboundary scientists, in order to meet the need for climate and connectivity models that seamlessly span the border, and to promote scientific engagement in transboundary adaptation processes. Such financial and structural supports for transboundary scientist and practitioner engagement will be key to maintaining a connected, resilient transboundary region as the climate changes.

## 9. MANAGEMENT APPLICATIONS AND PRODUCTS

Due to the collaborative nature of this project and numerous efforts to engage practitioners via in a variety of formats (e.g., workshops, webinars, phone calls, meeting and conference presentations), it is not possible to accurately list every manager who interacted with the project.  However, a partial list of participants who attended at least one project workshop is provided in Table 4.

**Table 4. Partial list of practitioners who participated in project workshops.**

| Partnership | Affiliation | Name | Contact |
|---|---|---|---|
| Parks/Forests | BC Parks | Tory Stevens | Tory.Stevens@gov.bc.ca |
| Parks/Forests | BC Parks | Kirk Safford | Kirk.Safford@gov.bc.ca |
| Parks/Forests | BC Parks | Joanna Hirner | Joanna.Hirner@gov.bc.ca |
| Parks/Forests | BC Parks | Mark Weston | Mark.Weston@gov.bc.ca |
| Parks/Forests | Parks Canada | Richard Pither | Richard.Pither@pc.gc.ca |
| Parks/Forests | BC FLNRO[1] | Orville Dyer | Orville.Dyer@gov.bc.ca |
| Parks/Forests | BC FLNRO[1] | Grant Furness | Grant.Furness@gov.bc.ca |
| Parks/Forests | BC FLNRO[1] | Dawn Marks | Dawn.Marks@gov.bc.ca |
| Parks/Forests | BC FLNRO[1] | Amy Nixon | Amy.Nixon@gov.bc.ca |

| | | | |
|---|---|---|---|
| Parks/Forests | BC FLNRO[1] | Eric Valdal | Eric.Valdal@gov.bc.ca |
| Parks/Forests | USFS[2] | Peter Singleton | psingleton@fs.fed.us |
| Parks/Forests | USFS[2] | Loren Everest | leverest@fs.fed.us |
| Parks/Forests | USFS[2] | Jesse Plumage | jplumage@fs.fed.us |
| Parks/Forests | USFS[2] | Rachel Lipsky | rslipsky@fs.fed.us |
| Parks/Forests | USFS[2] | Robert McGregor | macgregor@fs.fed.us |
| Parks/Forests | NPS[3] | Regina Rochefort | Regina_Rochefort@nps.gov |
| Parks/Forests | NPS[3] | Jason Ransom | Jason_I_Ransom@nps.gov |
| Parks/Forests | NPS[3] | Roger Christophersen | Roger_Christophersen@nps.gov |
| Parks/Forests | NPS[3] | Jack Oelfke | jack_oelfke@nps.gov |
| Parks/Forests | NPS[3] | Anne Braaten | Anne_Braaten@nps.gov |
| Tribes/First Nations | ONA[4] | Al Peatt | apeatt@syilx.org |
| Tribes/First Nations | ONA[4] | James Pepper | jpepper@syilx.org |
| Tribes/First Nations | LSIB[5] | Wendy Hawkes | referrals.coordinator@lsib.net |
| Tribes/First Nations | LSIB[5] | Tracy Lawlor | environment@lsib.net |
| Tribes/First Nations | USIB[6] | Lillian Gottfriedson | referrals@usib.ca |
| Tribes/First Nations | OIB[7] | Mandy Anderson | referrals@oib.ca |
| Tribes/First Nations | OIB[7] | Keith Louis | Keith.Louis@okanagan.org |
| Tribes/First Nations | PIB[8] | Lavonda Nelson | referrals@pib.ca |
| Tribes/First Nations | Consultant | Gregory Kehm | gregory.kehm@gmail.com |
| Tribes/First Nations | CCT[9] | Kody Jo Jaspers | KodiJo.Jaspers@colvilletribes.com |
| Tribes/First Nations | CCT[9] | Richard Whitney | Richard.Whitney@colvilletribes.com |
| Tribes/First Nations | CCT[9] | Mike Sanders | Mike.Sanders@colvilletribes.com |
| Tribes/First Nations | CCT[9] | Amelia Marchand | Amelia.Marchand@colvilletribes.com |
| Okanagan-Kettle | TCG[10] (UW[11]) | Andrew Shirk | ashirk@uw.edu |
| Okanagan-Kettle | TCG[10] (Consultant) | Rachel Holt | rachel@veridianecological.ca |
| Okanagan-Kettle | TCG[10] (Consultant) | Leslie Robb | robblar@homenetnw.net |
| Okanagan-Kettle | TCG[10] (ConsNW[12]) | Jen Watkins | jwatkins@conservationnw.org |
| Okanagan-Kettle | TCG[10] (SOSCP[13]) | Bryn White | Bryn.White@gov.bc.ca |
| Okanagan-Kettle | TCG[10] (UBC[14]) | Lael Parrott | lael.parrott@ubc.ca |
| Okanagan-Kettle | TCG[10] (OCCP[15]) | Susan Latimer | sdl.environmental@gmail.com |
| Okanagan-Kettle | TCG[10] (OCCP[15]) | Scott Boswell | occp123@gmail.com |
| Okanagan-Kettle | TCG[10] (OCCP[15]) | Tanis Gieselman | occp333@gmail.com |
| Okanagan-Kettle | TCG[10] (Consultant) | Alison Peatt | bearfootresources@shaw.ca |

1. BC Ministry of Forests, Lands, and Natural Resource Operations, 2. US Forest Service, 3. National Park Service,
4. Okanagan Nation Alliance, 5. Lower Similkameen Indian Band, 6. Upper Similkameen Indian Band,
7. Okanagan Indian Band, 8. Penticton Indian Band, 9. Colville Confederated Tribes,
10. Transboundary Connectivity Group, 11. University of Washington, 12. Conservation Northwest,
13. South Okanagan Similkameen Conservation Partnership, 14. University of British Columbia, Okanagan,
15. Okanagan Collaborative Conservation Program

We also engaged scientists and practitioners from partner and outside organizations to participate in expert review of our conceptual models of habitat connectivity (Table 5).

**Table 5. Expert reviewers for conceptual models of habitat connectivity.**

| Affiliation | Name | Species | Contact |
|---|---|---|---|
| USFS[1] | Dan Isaak | Bull trout | disaak@fs.fed.us |
| USFS[1] | Bob Keane | Whitebark pine | rkeane@fs.fed.us |
| USFS[1] | Kevin McKelvey | Wolverine | kmckelvey@fs.fed.us |
| BC Parks | Kirk Safford | Shrub steppe | Kirk.Safford@gov.bc.ca |
| BC FLNRO[2] | Orville Dyer | Shrub steppe, Tiger salamander | Orville.Dyer@gov.bc.ca |
| BC FLNRO[2] | Michael Murray | Whitebark pine | Michael.Murray@gov.bc.c |
| BC FLNRO[2] | Hillary Ward | Bull trout | Hillary.Ward@gov.bc.ca |
| BC MOE[3] | Carmen Cadrin | Shrub steppe | Carmen.Cadrin@gov.bc.ca |
| BC MOE[3] | Cliff Nietvelt | American marten, Mountain goat, Wolverine | Cliff.Nietvelt@gov.bc.ca |
| BC MOE[3] | Rich Weir | American marten, Wolverine | Rich.Weir@gov.bc.ca |
| Consultant | Mike Sarell | Tiger salamander | ophiucon@vip.net |
| Consultant | Les Gyug | Lewis's woodpecker | les_gyug@shaw.ca |
| Consultant | Alison Peatt | Black bear, Mule deer, Shrub steppe, Tiger salamander, Whitebark pine | bearfootresources@shaw.ca |
| WPZ[4] | Robert Long | American marten, Wolverine | Robert.Long@zoo.org |
| UW[5] | Greg Ettl | Whitebark pine | ettl@uw.edu |
| UW[5] | Andrew Shirk | Mountain goat | ashirk@uw.edu |
| ONA[6] WFN[7] PIB[8] LSIB[9] | Staff and community members (names withheld) | Black bear, Canada lynx, Lewis's woodpecker, Mule deer, Tiger Salamander | |

1. US Forest Service, 2. BC Ministry of Forests, Lands, and Natural Resource Operations,
3. BC Ministry of the Environment, 4. Woodland Park Zoo, 5. University of Washington,
6. Okanagan Nation Alliance, 7. Westbank First Nation, 8. Penticton Indian Band,
9. Lower Similkameen Indian Band

Based on discussions with practitioner partners, we expect project products will be used to inform diverse management decisions relevant to habitat connectivity and climate adaptation. These may include planning and other decisions by government agencies (federal, state/provincial, municipal, tribal and First Nation), environmental NGOs, or private landowners. For example, these products may inform:

- Land management plan revisions and decisions
- Wildlife management plan revisions and decisions
- First Nations and tribal referrals processes
- Private land stewardship

- Transportation planning
- Climate change vulnerability assessment
- Climate adaptation planning

## 10. OUTREACH
The collaborative nature of this project required regular, intensive outreach to project partners. We also conducted broader dissemination to share our project approach and findings with diverse audiences.  Outreach activities included:

*i. Workshops and webinars with project partners*
We engaged scientist and practitioner partners in a series of workshops and webinars to collaboratively execute project objectives. These included:

1. **Initial Workshops:** This first round of workshops oriented project partners to the project, and identified partner-specific goals and objectives for habitat connectivity management:
   - *US National Park Service, Sedro Wooley, WA (October 2014):* We held a workshop to orient National Park Service partners to the project and identify their goals and objectives regarding habitat connectivity management.
   - *US Forest Service, Everett, WA October 2014):* We held a workshop to orient Forest Service partners to the project and identify their goals and objectives regarding habitat connectivity management.
   - *Manning Provincial Park, BC (October 2014):* We held a workshop to orient partners from BC Parks, BC FLNRO, Okanagan Nation Alliance (including member bands), and Colville Confederated Tribes to the project and identify their goals and objectives regarding habitat connectivity management.
   - *Wildlinks Conference, North Cascades, WA (November 2014):* We held a break-out session to orient project partners who were unable to attend prior workshops, introduce them to other project participants, provide updates on project progress, and gather feedback.
   - *Peace Arch Park, Blaine, WA (December 2014):* We held a workshop for US NPS, USFS, BC Parks, and BC FLNRO managers. Meeting at the Peace Park circumvented barriers to international travel, providing an opportunity for practitioner partners to meet their counterparts from across the border. We drafted an initial list of case study species.

2. **Webinars and calls with practitioner partners:** We held numerous webinars and calls with project partners throughout the project to provide updates, gather feedback, and review interim and final products.

3. **Workshop II (***North Cascades, WA. June 2015)***:** We held a second workshop that successfully convened participants from each of the three project partnerships to review climate impacts on connectivity for case study species and systems, and develop adaptation strategies for addressing these impacts.

4. **Final workshops, webinars, and presentations.** We held a final set of workshops, webinars, and presentations to disseminate project products to a broader network of practitioners within partner agencies, NGOs, and tribes and First Nations.  These included:

- *BC Parks, BC FLNRO, BC Ministry of Environment. Victoria, BC (March 2016):* We delivered a keynote address to a conference of BC provincial biologists, describing the project and the availability of project products on Data Basin.

- *US National Park Service. Sedro Wooley, WA (March 2016):* We held a workshop describing the project and providing hands-on training in the use of project products on Data Basin.

- *Okanagan Nation Alliance and Colville Confederated Tribes. Kelowna, BC (March 2016):* We held a workshop describing the project and providing hands-on training in the use of project products on Data Basin.

- *Okanagan-Kettle Region Stakeholders. Penticton, BC (March 2016):* We held a workshop describing the project and providing hands-on training in the use of project products on Data Basin.

- *US Forest Service. Region 6 Biologists. (April 2016):* We gave a webinar describing the project and the availability of project products on Data Basin.

*ii. Broader dissemination*

We disseminated our project approach and findings to a broader audience via conference presentations, webinars, and workshop presentations. These included:

1. **Conference presentations**
   - *National Adaptation Forum. St. Louis, MO (May 2015)*
   - *International Congress for Conservation Biology. Montpellier, FR (August 2015)*
   - *Wildlinks Conference. Manning Park, BC (October 2015)*
   - *Northwest Climate Conference. Coeur D'Alene, ID (November 2015)*
2. **Webinars**
   - *Association of BC Forest Professionals. Webinar.* (*March 2016*)
3. **Workshop presentations**
   - *NW CSC Executive Stakeholder Advisory Committee Meeting. Portland, OR* (*October 2014*)
   - *Osoyoos Lake Water Science Forum "A Watershed Beyond Boundaries: Stewardship of our Shared Waters." Osoyoos, BC (October 2015)*

*iii. Publications*

1. **Reports**
   - We completed an overview report describing the project process, partners, methods, results, and lessons learned:

- o Krosby, M., Michalak, J., Robbins, T.O., Morgan, H., Norheim, R., Mauger, G., and T. Murdock. 2016. The Washington-British Columbia Transboundary Climate-Connectivity Project: Identifying climate impacts and adaptation actions for wildlife habitat connectivity in the transboundary region of Washington and British Columbia. Climate Impacts Group, University of Washington. Available at: https://nplcc.databasin.org/galleries/5a3a424b36ba4b63b10b8170ea0c915e
- We completed reports describing findings for each of the individual case study species, vegetation system, and regions. These were prepared as stand-alone appendices to the overview report. Available at: https://nplcc.databasin.org/galleries/5a3a424b36ba4b63b10b8170ea0c915e
  - o Appendix A: Wolverine
  - o Appendix B: Mountain goat
  - o Appendix C: White-tailed ptarmigan
  - o Appendix D: Whitebark pine
  - o Appendix E: Canada lynx
  - o Appendix F: American marten
  - o Appendix G: Black bear
  - o Appendix H: Mule deer
  - o Appendix I: Lewis's woodpecker
  - o Appendix J: Tiger salamander
  - o Appendix K: Bull trout
  - o Appendix L: Shrub-steppe
  - o Appendix M: Okanagan-Kettle region

2. **Interactive Online Products**
   - We made all reports and associated models and map products created or gathered as part of this project freely available to project partners and the general public via the online mapping platform, Data Basin. Available at: https://nplcc.databasin.org/galleries/5a3a424b36ba4b63b10b8170ea0c915e

3. **Peer-reviewed Articles**
   - We are preparing a manuscript for a peer-reviewed journal that will describe our approach and findings for addressing climate impacts on habitat connectivity. Target journal: *Frontiers in Ecology and the Environment*. Target submission date: *June 2016*.
     - o Krosby, M., Michalak, J., Robbins, T.O., Morgan, H., Norheim, R., Mauger, G., and T. Murdock. (*in preparation)* Assessing climate impacts and adaptation responses for wildlife habitat connectivity: A case study from the transboundary region of Washington and British Columbia.